THE REPUBLIC OF UGANDA

MINISTRY OF ENERGY AND MINERAL DEVELOPMENT

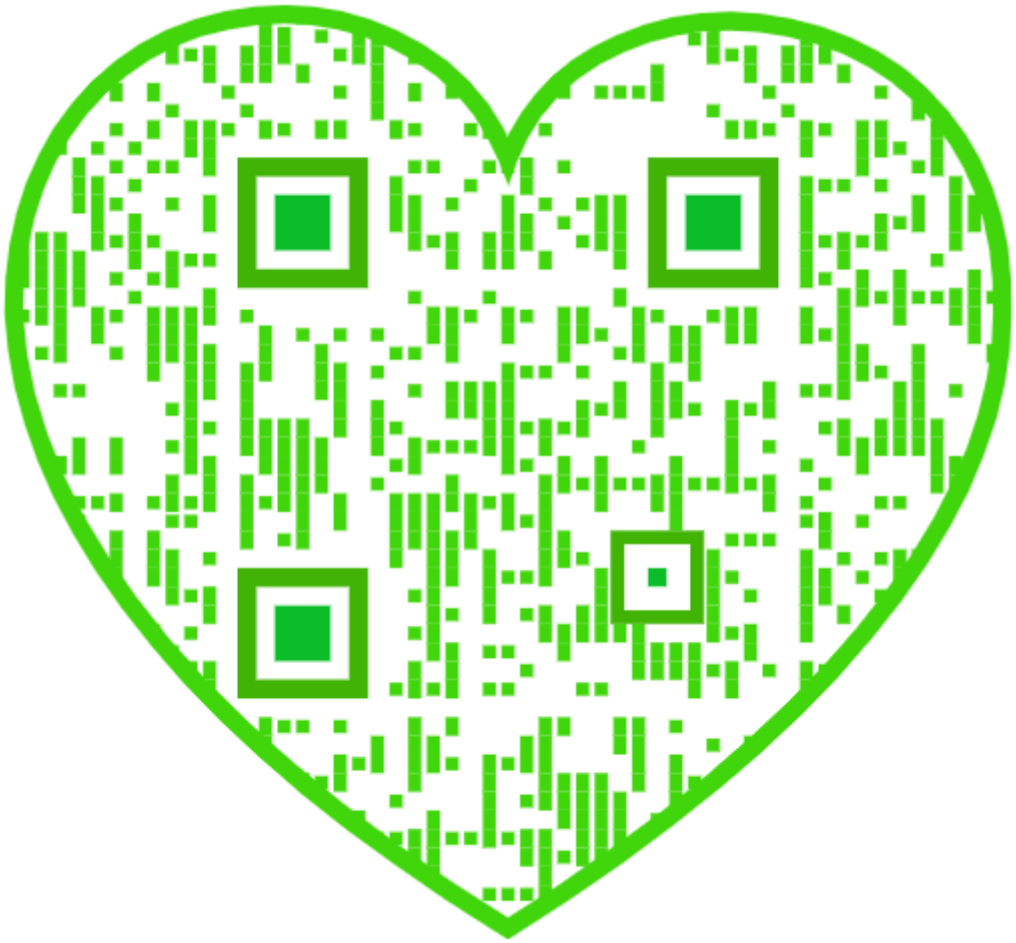
Energy Advisory Project

HOW TO BUILD THE IMPROVED HOUSEHOLD STOVES

A CONSTRUCTION MANUAL FOR THE ROCKET – LORENA AND SHIELDED FIRE STOVES

With the Support of the German Technical Cooperation

November 2004



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Introduction

Uganda faces a biomass energy crisis marked by an increasing imbalance between the supply and the demand of the firewood by households, institutions and industries.

One of the most effective strategies to sustainably contribute towards the reduction of this problem is through an extensive dissemination of biomass energy efficient technologies.

The purpose of this manual is to provide to all interested parties a practical tool to use in the construction of improved firewood stoves i.e the rocket – lorena and the shielded fire.

The improved biomass energy efficient technologies have been developed to improve energy efficiency for household, institutional and industrial practices. They include the domestic and institutional firewood stoves and the firewood baking oven.

These improved household stoves have efficiencies of 30 % (average) compared to the traditional (open) 3-stone fire stove at 15.6 %, in a high power water-boiling test[*].

The main objective in developing the improved firewood stoves is to achieve relatively efficient firewood combustion and maximising heat transfer to the food being cooked.

These improved stoves help the users to have firewood savings of 50 – 60 % when compared to the traditional (open) 3 stone stove. Yet another strength of these stoves is that they are built using local materials including clay, anthill soil and sand for the body whereas insulating materials include sawdust, pumice and vermiculite.

[*] Data source: GTZ – EAP / MEMD records. “Firewood Cook stoves Development and Testing” by Leonard Mugerwa, September 2003.

THE IMPROVED FIREWOOD STOVES

The improved stoves are able to achieve maximum transfer of heat to the food because they heat at least 90 % of the saucepan's surface area and have insulation around the combustion chamber and the fire passages.

Advantages

1 Firewood Fuel Savings

The stoves have been tested and proven to be economical in firewood consumption, with an efficiency averaging 30% compared to the traditional (open) 3-stone fireplace at 15.6%. This means that by using the improved stove, you double the amount of energy is transferred from the wood to the food being cooked.

2 Almost Smokeless Operation

The stoves hardly produce smoke during their operation. A bit of smoke is produced only when lighting the fire.

3 Easy to Operate

Once lit, the stove fire does ***not*** stop unless firewood feed into the stove is stopped. There is ***no need*** of straining one's lungs to blow air into the stove to fan the flame as it is with the Traditional (open) 3-stone fire. This is done by the air chamber below the feeding shelf.

4 Affordable

The stoves are constructed using local materials including anthill soil and sand for the body whereas vermiculite, sawdust, pumice, etc are used for thermal insulation.

5 Safe to Use

The stoves are safe-to-use domestic appliances. Firewood is neither toxic nor highly inflammable. The shielded fire is screened (out of reach) and therefore less likely to cause burns to children and the user.

6 Environmentally Friendly

The stoves use less firewood leading to reduction of the deforestation rate. The stoves are less pollutant because of their nearly smokeless operation, attributed to the shelf-fitted rocket elbow combustion chamber, which improves the air : fuel ratio.

THINGS TO CONSIDER WHEN PREPARING TO BUILD THE IMPROVED STOVES

1.0 SHELTER

Ensure that there is a kitchen in place to house and protect the stove to be built from intrusion and unfavourable weather conditions e.g. rain.

2.0 TOOLS

The tools required when building the improved firewood stoves include:

	Tool	Purpose
1	Hoe	Digging foundation base and mixing ingredients
2	Shovel or Spade	Mixing ingredients
3	Jerry can	Fetching water
4	Sieve (4 mm)	Sifting ingredients
5	Trough *(karaayi)*	Measuring materials by volume and carrying mixtures
6	Trowel / blunt machete	Smoothing plaster / stove finish
7	Measuring Tape / ruler	Taking measurements
8	Bow saw	Cutting pumice blocks into insulation slabs
9	Spirit level (optional)	Inspecting horizontal level for laid bricks / stove finish
10	Plumb line (optional)	Inspecting vertical alignment for laid bricks / structure
11	Try Square (optional)	Inspecting right angled corners

Safety Gear[1]

	Device	Purpose
1	Nose Mask	Protection against inhaling dust during sifting
2	Overalls / work clothes	Protection of clothes during work
3	First Aid Kit[2]	Treatment for injuries

[1] Recommended for use where available.
[2] Professional workshop practice recommends that a First Aid kit should be in place.

3.0 STOVE CONSTRUCTION MATERIALS

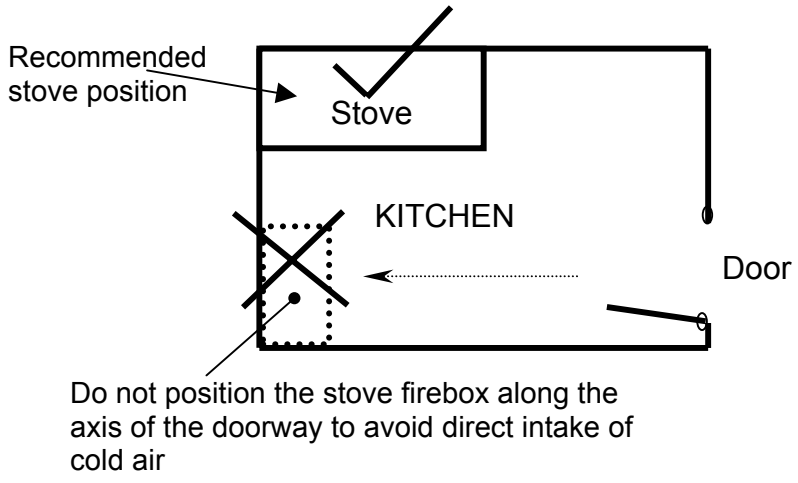
	Materials	Options	Quantity	
			Rocket - Lorena	Shielded Fire
1	Clay	Anthill soil	8 – 12 wheel barrows	4 – 6 wheel barrows
2	Sawdust	Dry chopped grass, dry chopped banana leaves, vermiculite or pumice	8 – 12 wheel barrows	4 – 6 wheel barrows
3	Mud bricks	-	60 – 80 bricks	10 bricks
4	Clay tile	-	1 pc (25 x 13 x 1 cm)	1 pc (25 x 13 x 1 cm)
5	Water	-	7 – 10 jerry cans (20 litres each)	4 jerry cans (20 litres each)
6	Sand	-	8 – 12 wheel barrows	4 – 6 wheel barrows

4.0 PURCHASE AND DELIVERY OF MATERIALS

Purchase the construction materials and deliver them outside the kitchen where the stove is to be built.

5.0 MAPPING OUT THE STOVE POSITION

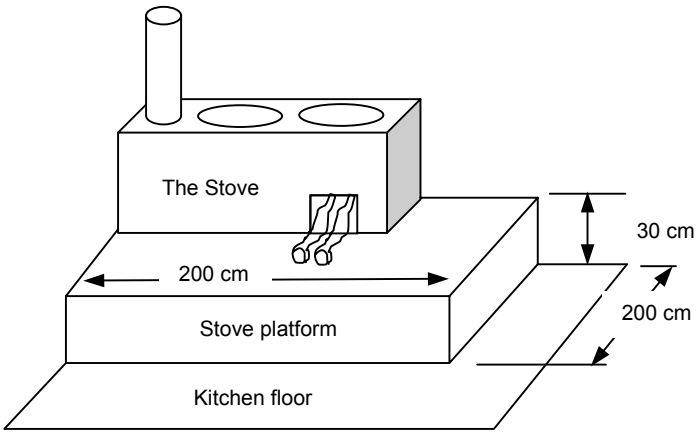
Choose a corner in the kitchen to be occupied by the stove. This will save it from accidental damage and it will also be useful in preventing the stove from direct intake of cold air.


Recommended stove position
Stove
KITCHEN
Door
Do not position the stove firebox along the axis of the doorway to avoid direct intake of cold air

Kitchen plan

NOTE:

It is advisable that one week prior to stove construction, a 200 X 200 X 30cm high platform be built in the kitchen corner that has been marked above. On this platform, the stove will be constructed. This will help to keep the stove out of reach for very young children.



6.0 MATERIALS PREPARATION

Prepare the construction materials, at least two days before the time for stove construction. The preparation procedure will depend on the materials combination chosen as described below:

6.1 Sawdust and clay (or anthill soil option)

6.1.1 Crash the clay (or anthill soil) into smaller granules, which can be sieved through the 4 mm sieve.

6.1.2 Using the sieve, sift the clay (or anthill soil) to obtain fine granules.

In the same way sift an equal amount of sawdust to obtain fine particles.

6.1.3 Mix the sifted sawdust and clay (or anthill soil) in a volumetric ratio 1:1.

6.1.4 Slowly add water to the mixture to make it mouldable.

6.1.5 Blend the mixture using the feet similar to the way it is locally done when preparing mud for brick making.

In the event that sawdust is not available in your place, you may use any of the following stove construction materials combination depending on availability:

6.2 Grass and clay (or anthill soil option)

6.2.1 Use the machete *(panga)* to chop dry grass into small pieces of approximate length 1 cm.

6.2.2 Using the sieve, sift the clay (or anthill soil) to obtain fine ingredients.

6.2.3 Mix the chopped dry grass and clay (or anthill soil option) volumetric ratio 1:1.

6.2.4 Slowly add water to the mixture just to make it mouldable.

6.2.5 Blend the mixture using feet similar to the way it is locally done when preparing mud for brick making.

6.3 Dry banana leaves and clay (or anthill soil option)

6.3.1 Separate the stalk and mid-rib from the lamina. Use the dry lamina of the dry banana leaves.

6.3.2 Use the machete *(panga)* to chop the dry lamina into small pieces of approximate length 1 cm.

6.3.4 Using the sieve, sift the clay (or anthill soil) to obtain fine ingredients.

6.3.5 Mix the chopped lamina and clay (or anthill soil option) volumetric ratio 1:1.

6.3.6 Slowly add water to the mixture just to make it mouldable.

6.3.7 Blend the mixture using feet similar to the way it is locally done when preparing mud for brick making.

6.4 Pumice, anthill soil and sand.

6.4.1 Using the sieve, sift the sand and clay (or anthill soil) separately to obtain fine ingredients.

6.4.2 Mix the clay (or anthill soil) and sand (ratio 1:1).

6.4.3 Slowly add water to the mixture just to make it mouldable.

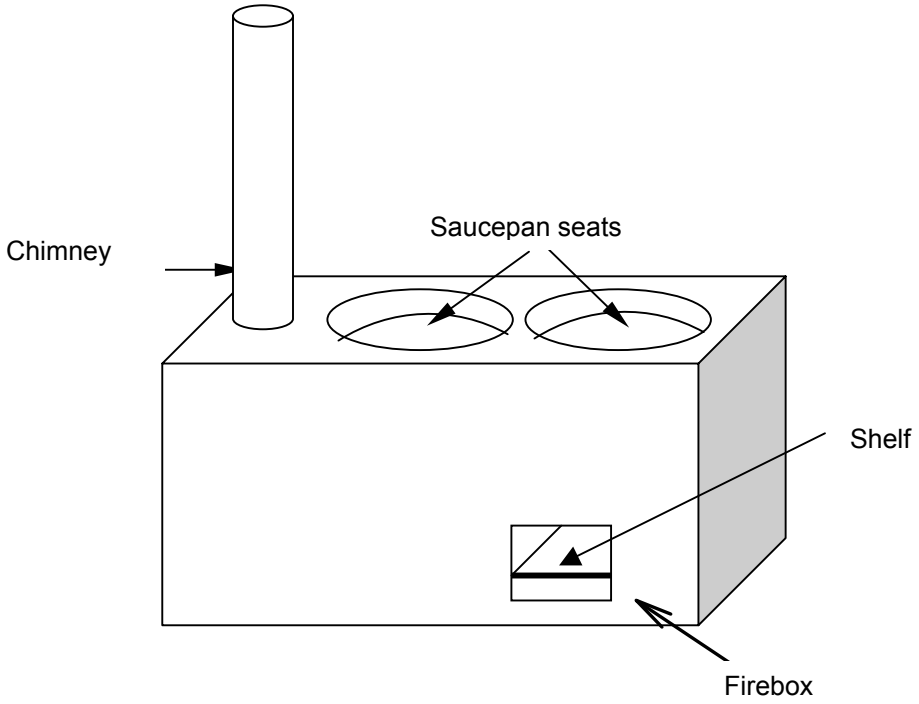
6.4.4 Blend the mixture using feet similar to the way it is locally done when preparing mud for brick making.

6.4.5 Cut / shape the pumice into slabs of 5cm thickness.

Note: The slabs will later be used in providing thermal insulation around the combustion chamber and the fire (hot flue gases) passage. They will be fastened together using the anthill soil – sand mixture.

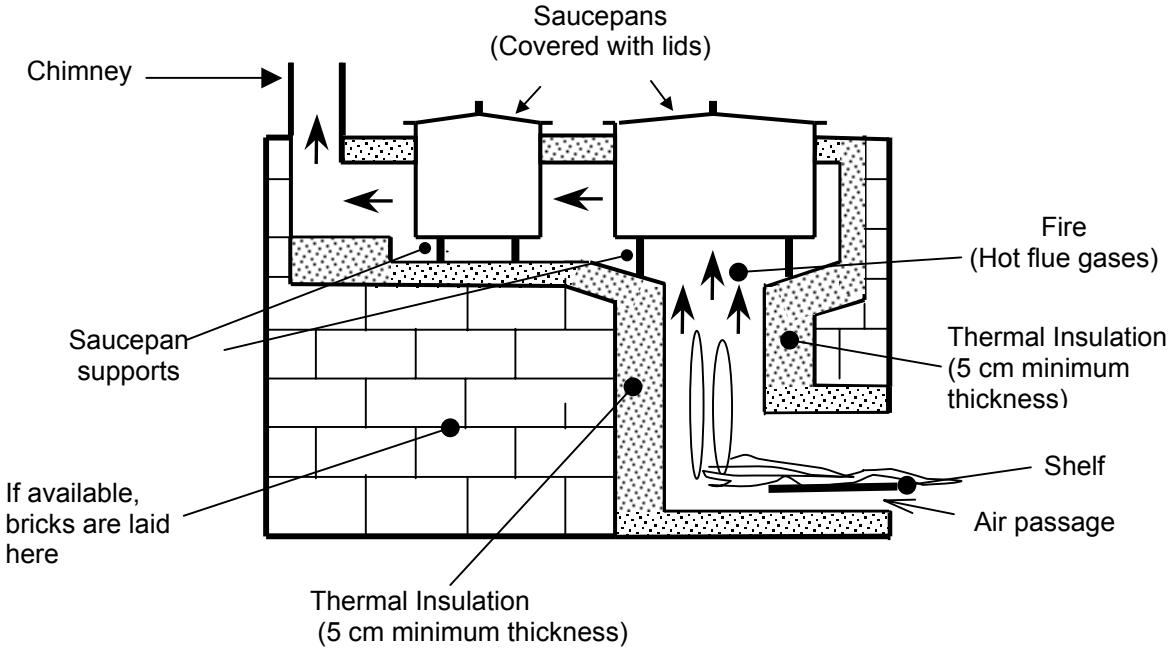
PART 1

HOW TO BUILD THE IMPROVED ROCKET - LORENA STOVE



HOW THE ROCKET LORENA STOVE WORKS

Below is the sectioned front view of the stove, showing how it is intended to function. Note that the saucepan seats are deep enough to have the saucepans submerged into the stove's hot gases' passage. This increases the surface area of the saucepan being exposed to the fire (hot flue gases), which results into increased heat transfer into the saucepan.



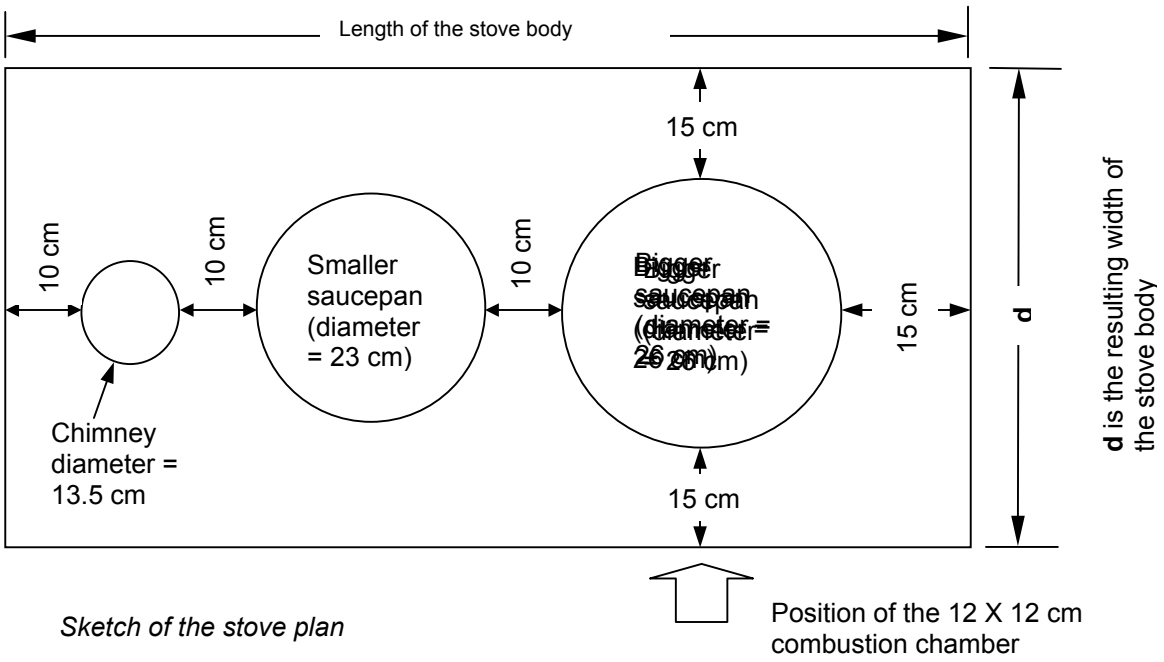
7.0 Building the Rocket - Lorena Stove

The size of the stove will depend on the size of the saucepans that will be used when cooking with it.

Example:

For a home that frequently uses two saucepans with diameter 26 cm and 23 cm, the bigger saucepan should be positioned directly above the combustion chamber while the smaller one takes the other position. The size of the combustion chamber will be 12 X 12 cm (or circular option diameter = 13.5 cm). This will be the inner diameter of the chimney.

The stove designed for 26 cm bigger diameter and 23 cm smaller diameter saucepans will have the resulting outer dimensions = 107 X 56 cm.



Sketch of the stove plan

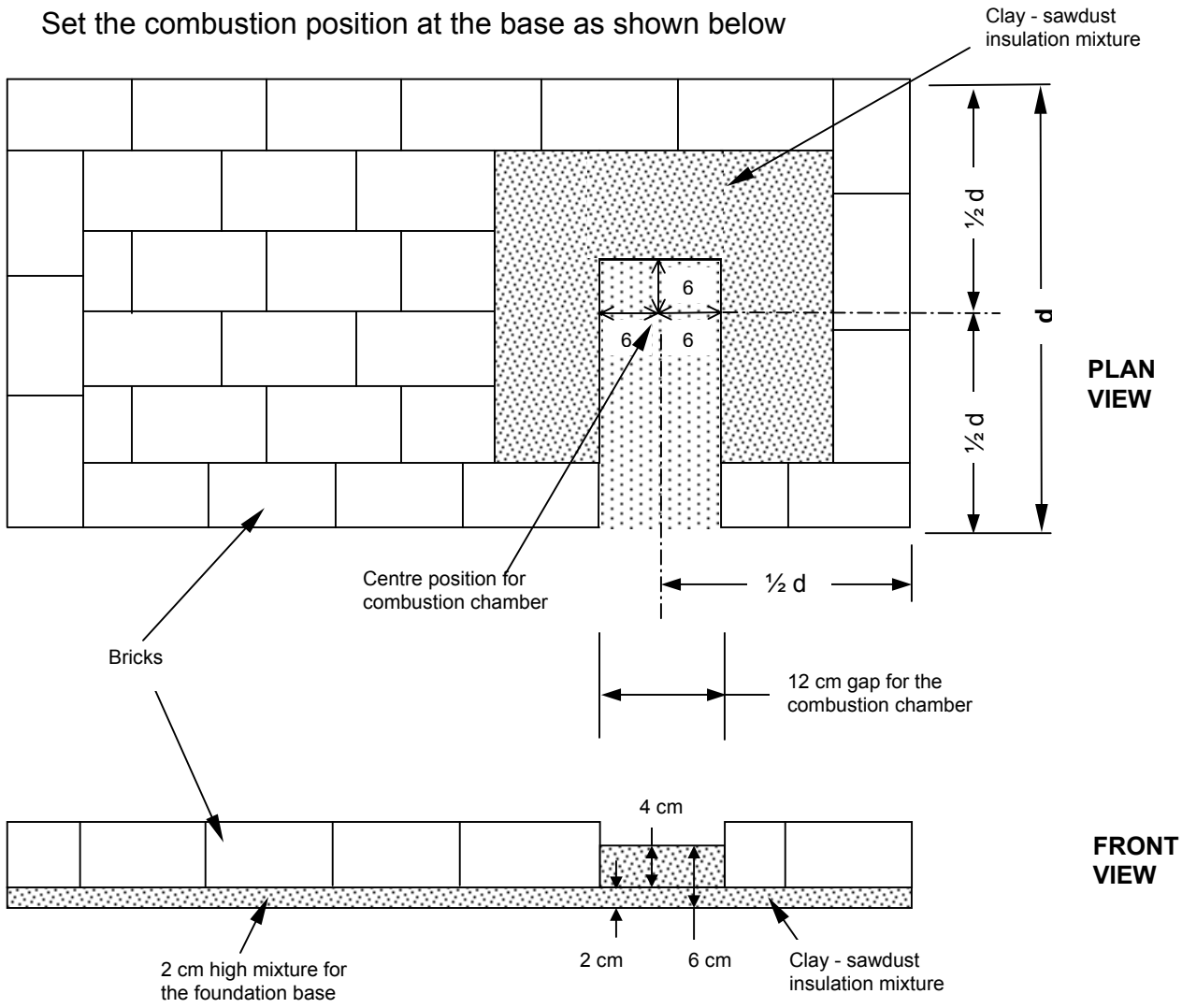
Draw the outline of the stove foundation on the platform as illustrated above. The bigger saucepan should be positioned directly above the combustion chamber while the smaller one takes the other position. In the event that a measuring tape is not available, use the palm width. The width of your palm approximates 10 cm. For the 15 cm measurement use 1½ palm widths.

7.1 Wet the position to be occupied by the stove. Using the mixture in 6.1.5 above, lay down a 2 cm high base for the stove, bordered by the marked out line.

7.2 Lay the foundation bricks on the 2 cm high mixture. If bricks are not available, use the sawdust-clay mixture.

7.3 While setting the foundation the combustion chamber base should be catered for as shown. For example if the bigger saucepan diameter is 26 cm, build a 12 cm wide combustion chamber (refer to the tables in appendix).

7.4 Set the combustion position at the base as shown below



7.5 Building the combustion chamber

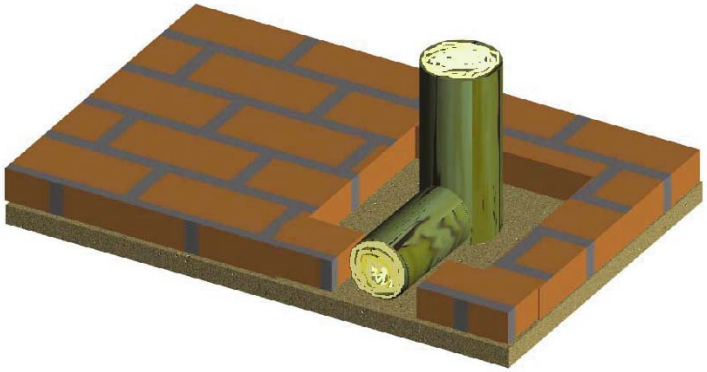
You will need some material to mould the combustion chamber shape during stove construction.

In order to build a square cross section combustion chamber of 12 X 12 cm for support use square cross section bricks of same size (12 X 12 cm) covered in polythene material.

For the option of a circular combustion chamber use diameter = 13.5 cm.
(For details of the calculation, refer to appendix 1).

The worked example of the 26 and 23 cm diameter saucepans will be illustrated with the construction of a stove with a circular combustion chamber of diameter 13.5 cm.

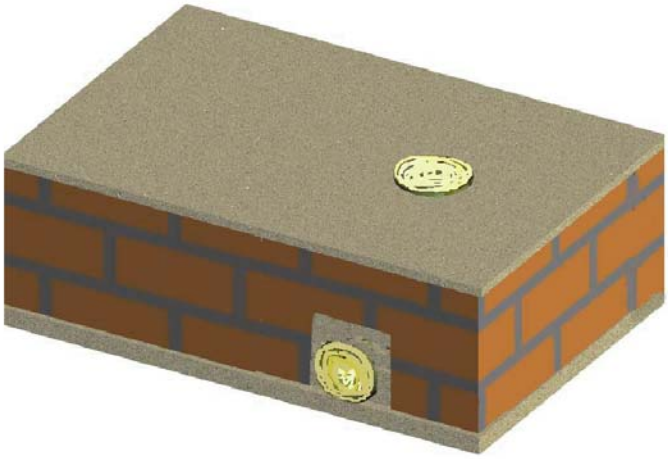
- Cut a banana stem, and remove its outer layers to reduce its diameter to 13.5 cm.
- Cut it into segments one of which is to be positioned vertically and the other one horizontally.
- The length of the horizontal one should be equal to ½ d plus 10 cm.
- Note: (= 1/2 d = half of stove base width).
- The **vertical** one should be equal to the value of H given in the appendix.



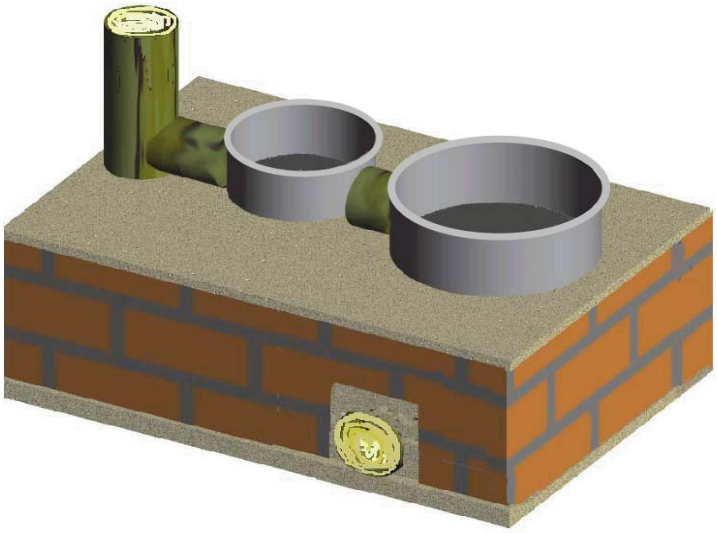
Example:

- Using a 26 cm diameter saucepan, combustion chamber = 12 cm wide, H = 30 cm; which implies that:
- The vertical banana stem is 30 cm high.
- The stove width is (26 +30) = 56 cm = d.
- Therefore ½ d = ½ X d = ½ X 56 = 28 cm.
- The horizontal stem then becomes 28 +10 = 38 cm

7.6 Continue constructing the stove up to the level at which the vertical banana stem just gets covered



- Measure out the positions of the saucepans, the chimney and the 10 cm gaps between them.
- Wet the outside of the saucepans (to ease their removal from the mixture).
- Position the big saucepan such that the centre of its bottom sits at the centre of the vertical banana stem, then put the smaller saucepan in the other position (as shown).
- Place a vertical banana stem in the chimney position.
- Place horizontal banana stem segments each of length 10 cm between the saucepans and the chimney position.



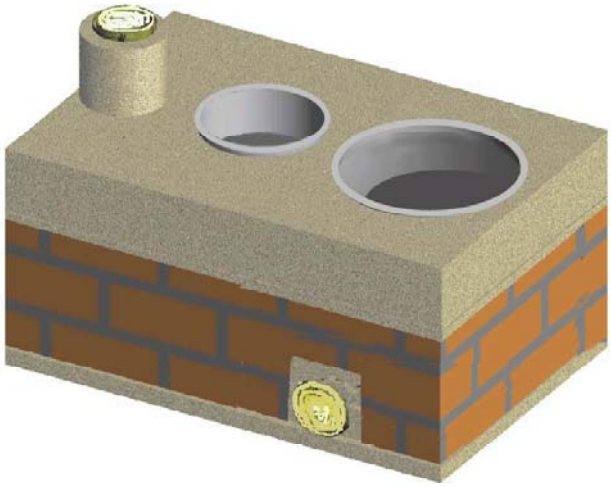
Note: The diameter of the banana stems should also be equal to the one used for the combustion chamber (= 13.5 cm).

- Place bricks in the saucepans to hold them in position, as shown.
- Fill the space around the saucepans with the insulation mixture.

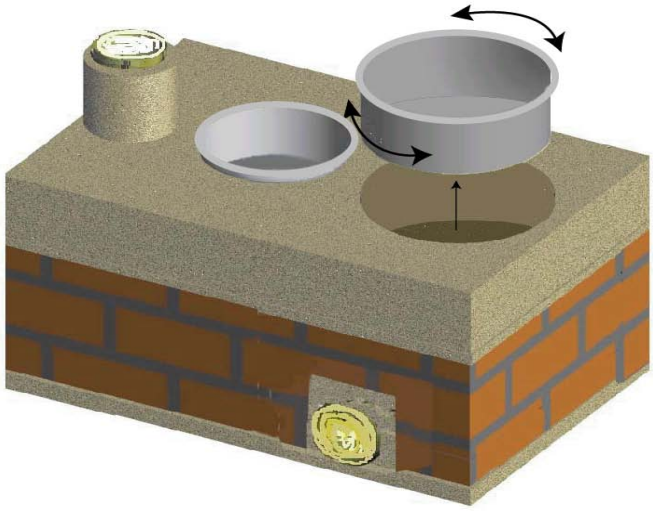
7.7 Build the insulation mixture around the saucepans up to the saucepan rim height. The horizontal banana stems should also be covered.

Using the mixture, build around the vertical banana stem to form the chimney.

The banana stems occupy the fire (hot flue gases) passage and will be removed at a later stage.



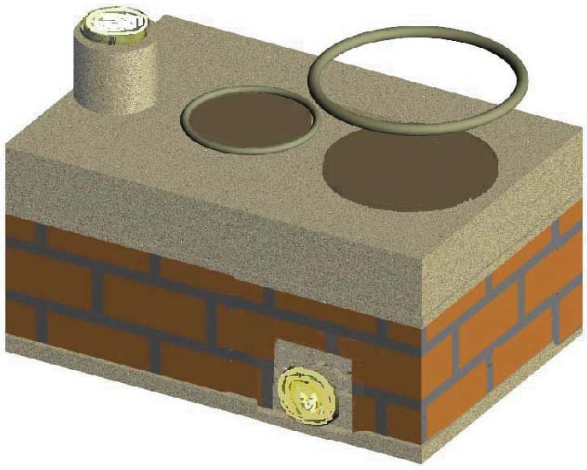
Remove the saucepans carefully by rotating back and forth while lifting out.



7.8 Cut out 2.5 cm thickness of the layer around the saucepan seats to create room for the hot gases to have contact around the saucepans.

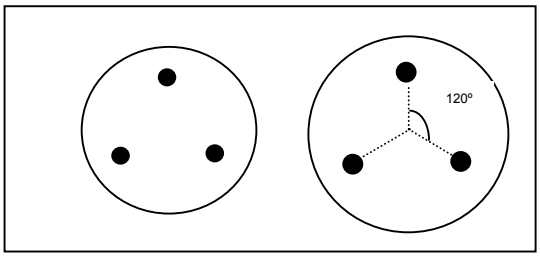
If you do not have a measuring tape, use the length of the first segment of your index finger, which approximates 2.5 cm.

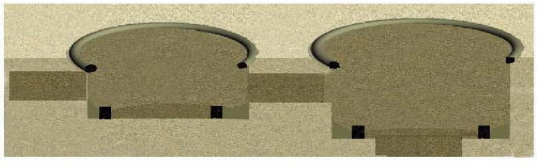
Roll some of the insulation mixture in your palms and fit it around the saucepan seats to form a neck.



Using the insulation mixture, build 3 saucepan supports of 2.5 cm high each, inside each of the saucepan seats.

The supports should be uniformly spaced (at 120º) from each other.





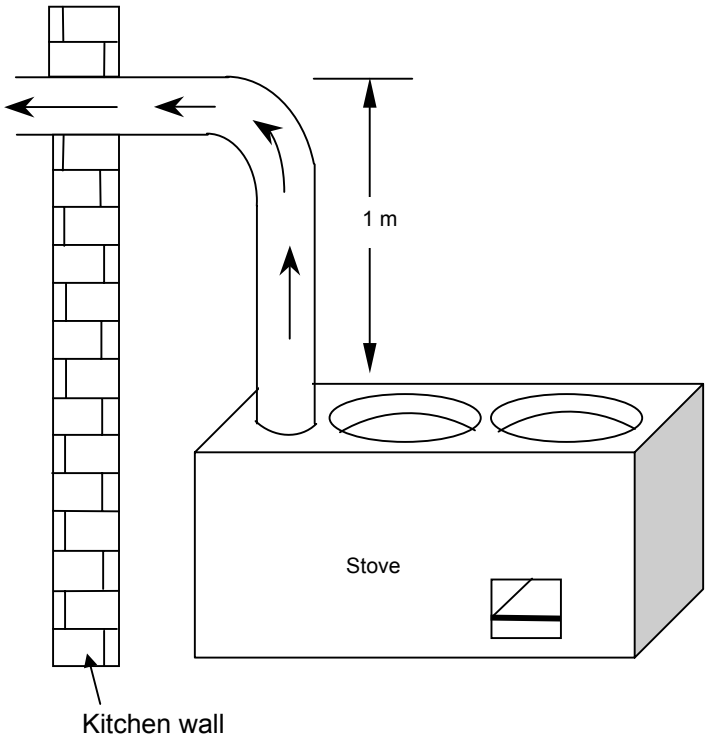
7.9 Finishing the stove construction

- Plaster the stove body to give it a good finish. You may use any of the materials that are used to plaster mud walled huts (e.g. a mixture of sand, cow dung, water etc)
- Use wet fingers and a trowel to smooth the finish such that the stove is completely without cracks
- If available use the spirit level to ensure that the top surface is horizontal. (Optional)

- Leave the stove block to dry for 4 weeks, while covered with a watertight material e.g. polythene sheet (*kavera*) or banana leaves.
- The stove should be shielded from sunshine.
- Do not allow children or animals to play on or near it.

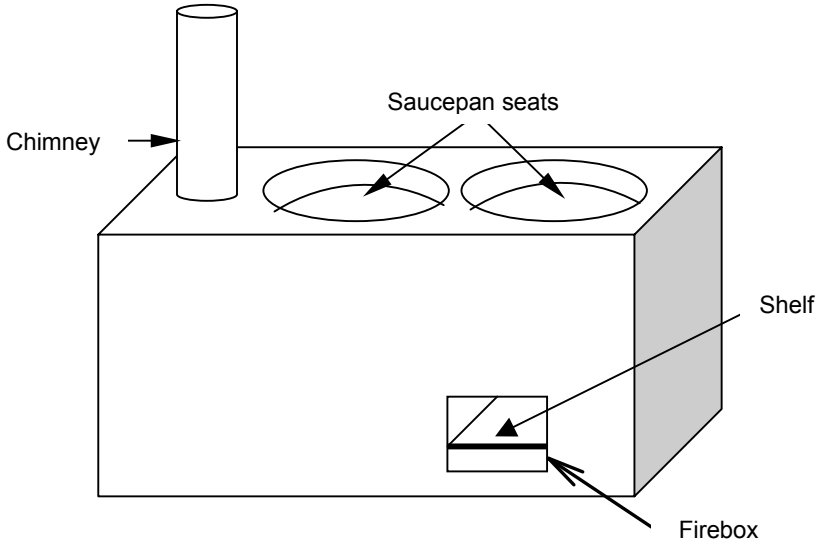
After 4 weeks of drying;

- Remove the now shrunk banana stems from the stove body.
- Smooth the hot gases passage using wet hands.
- Use the form of insulation mixture to complete the construction of the chimney to direct the smoke (stove exhaust) outside the kitchen through the wall as shown.



<u>NOTE:</u>
By this time if the stove body may have cracked during the drying process, seal the cracks using the original form of mixture that was used to build it.

7.10 Fitting the firewood shelf



- Fit a firewood shelf in the stove's firewood feed chamber (firewood magazine).

Note:

The outside finishing of the stove body may be made using the methods commonly applied for the finishing of the mud walled huts in the community e.g. using a mixture of sand, cow dung and water.

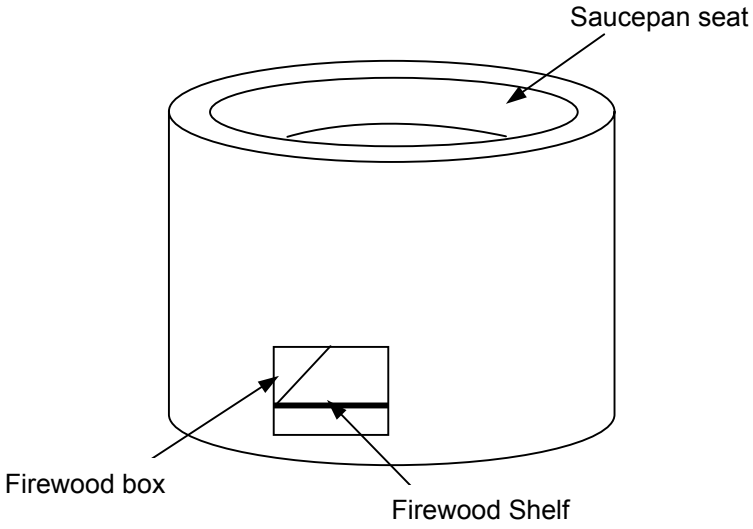
This helps to prevent the stove body surface from cracking and it also makes it fairly watertight and fine looking.

The Finished Rocket – Lorena Stove

For details on fitting of the firewood shelf, stove usage, cleaning and maintenance, refer to the section that follows the shielded fire stove (Part 2) on page 21.

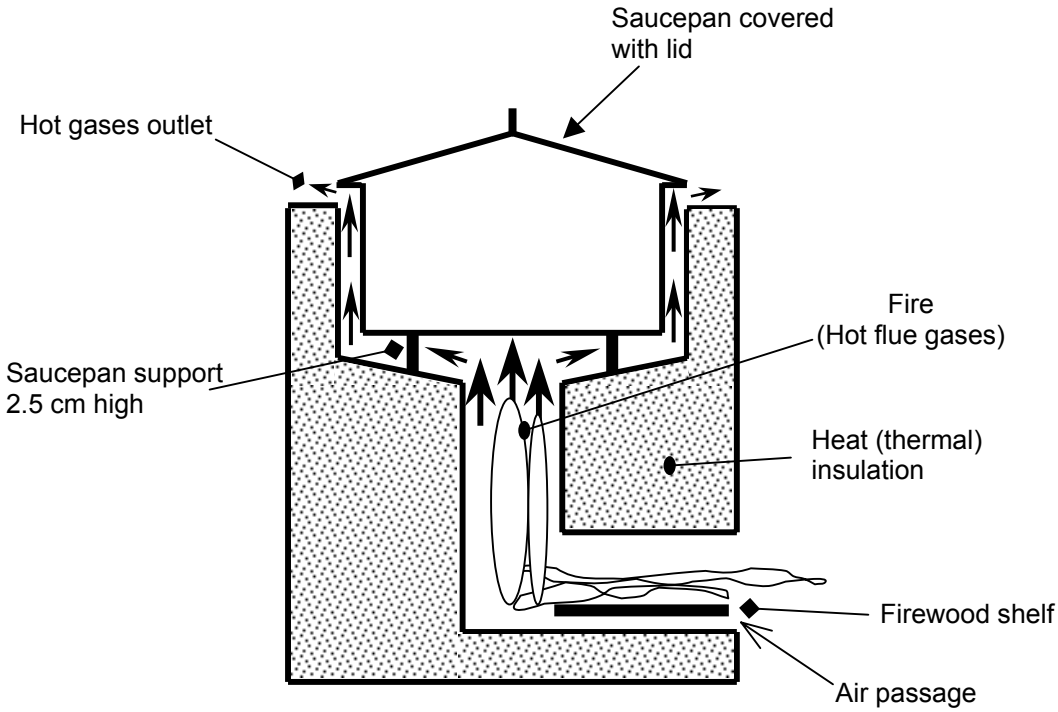
PART 2

HOW TO BUILD THE SHIELDED FIRE STOVE



HOW THE SHIELDED FIRE STOVE WORKS

Below is the section view of the stove showing how it is intended to function. Similar to the two-pot rocket lorena, the saucepan seat should be deep enough to have the saucepan submerged into the stove's body. This increases heat transfer into the saucepan.



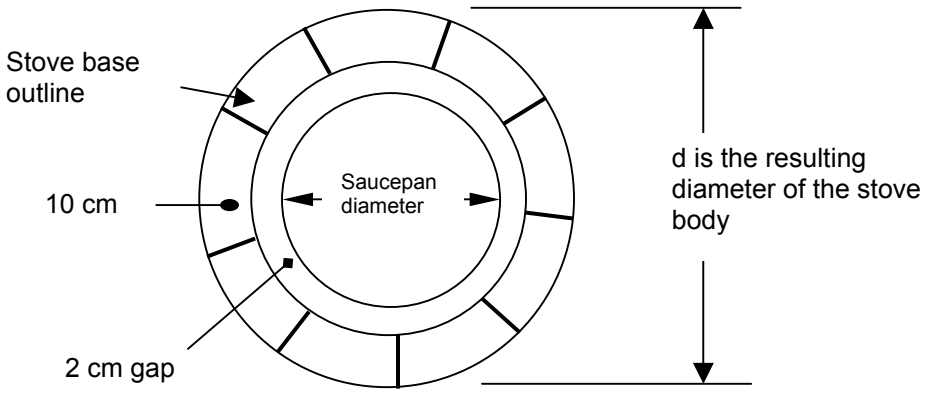
8.0 Building the shielded fire stove

The size of the stove will depend on the size of the saucepan that will be used when cooking with it.

Example:

For a home that frequently uses a saucepan with diameter 26 cm, the size of the combustion chamber will be 12 X 12 cm (or circular option diameter = 13.5 cm).

The stove designed for 26 cm diameter saucepan will have the resulting outer diameter = 50 cm (Calculation shown on the next page).



8.1 Laying the stove foundation

- Using the mixture, lay down a 2 cm high base for the stove, bordered by the marked outline.
- Lay the foundation bricks on the 2 cm high mixture. If bricks are not available, use the sawdust – clay mixture.
- While setting the foundation care should be taken to ensure that the combustion chamber is centred.

If the saucepan diameter = D, the resulting stove base diameter d = D + 24 cm, and combustion chamber width = J.

For example when using a saucepan of 26 cm, the resulting stove diameter d = D + 24 = 26 + 24 = 50 cm.

The combustion chamber width J = 12 cm from the tables on the last page.

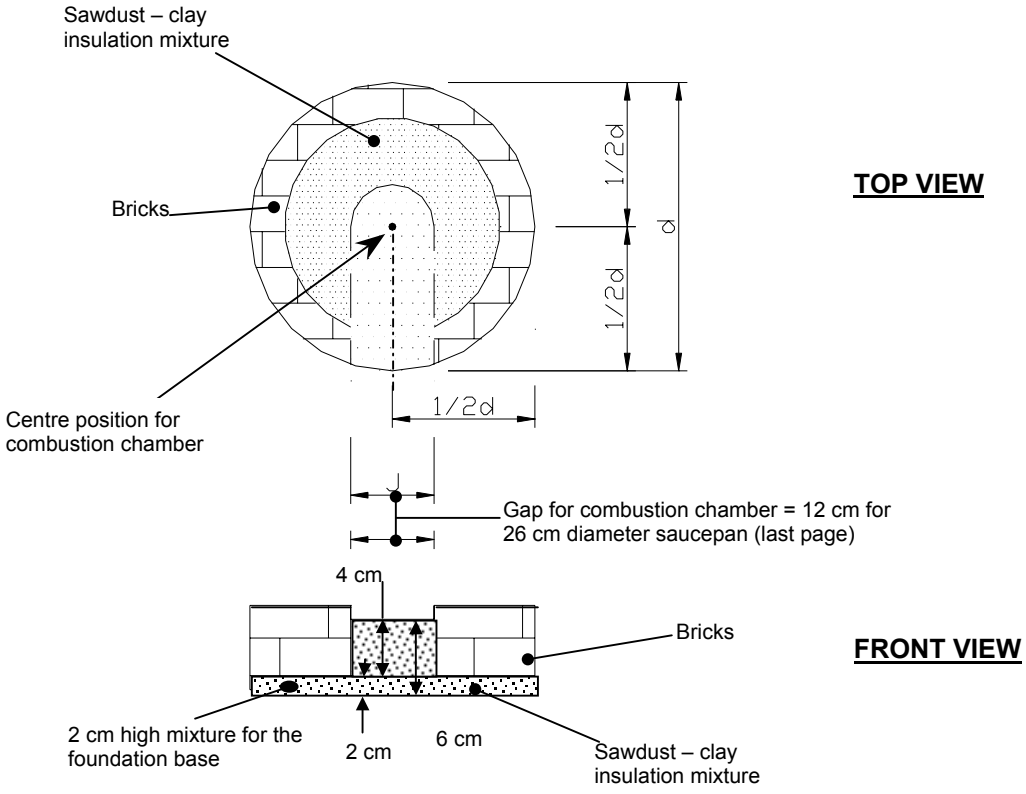


Diagram: Setting the combustion chamber position at the base

8.2 Constructing the combustion chamber

- Cut a banana stem, and remove its outer layers to reduce its diameter to 13.5 cm.
- Cut it into segments one of which is to be positioned vertically and the other one horizontally.
- The length of the horizontal one should be equal to ½ d plus 10 cm.
- Note: (= 1/2 d = stove radius).
- The **vertical** one should be equal to the value of H given in the appendix.

Example:

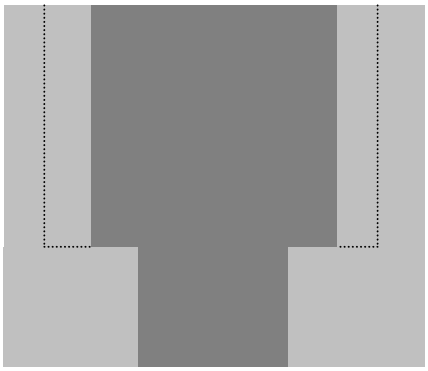
- Using a 26 cm diameter saucepan, combustion chamber = 12 cm wide, H = 30 cm; which implies that:
- The vertical banana stem is 30 cm high.
- The stove diameter 50 cm = d.
- Therefore ½ d = ½ X d = ½ X 50 = 25 cm.
- The horizontal stem then becomes 25 +10 = 35 cm.

8.3 Constructing the stove body

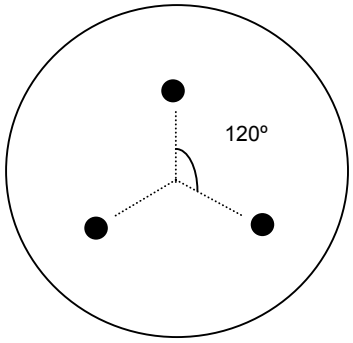
Continue constructing the stove using the mixture up to the level, which the vertical banana stem just gets covered. Level the top of the stove structure.

8.4 Constructing the saucepan seat

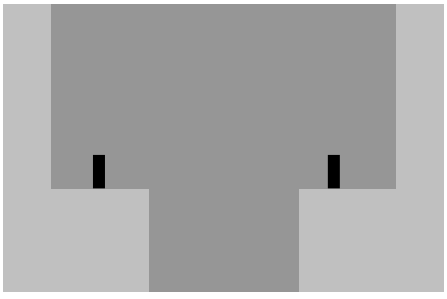
- Wet the outside of the saucepan using a mixture of wood ash and water (to ease its removal at a later stage).
- Position the saucepan such that the centre of its bottom sits at the centre of the vertical banana stem, and then place a considerable weight (e.g. a piece of brick) in the saucepan to hold it in position.
- Fill the space around the saucepan with the insulation mixture (as shown below) up to the
- Remove the saucepan carefully by rotating back and forth while lifting out.



- Cut out a 2.5 cm thickness of the layer around the saucepan seat to create room for the hot gases to have contact around the saucepan.
- If you do not have a measuring tape, use the length of the first segment of your index finger, which approximates 2.5 cm.

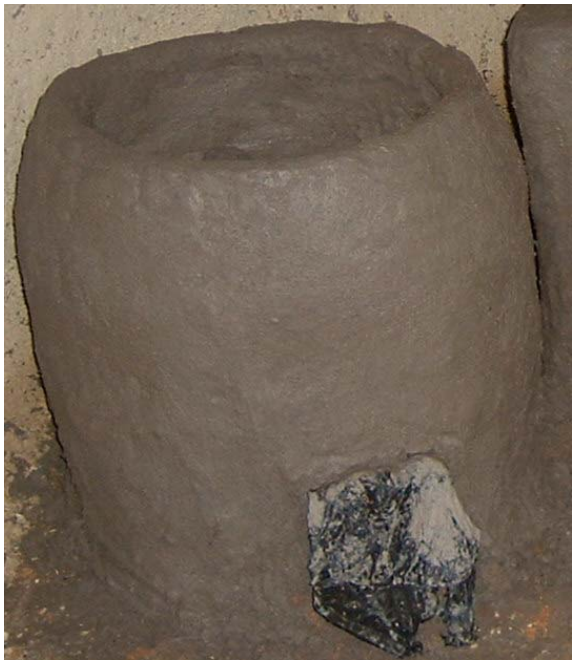


- Inside the saucepan seat, build 3 saucepan supports using the insulation mixture e.g. sawdust and clay, each measuring 2.5 cm high.
- Position them in a radial form, with an angular space of 120^{o} from each other to ensure uniform spacing.
- These will hold the saucepan high enough to allow hot gases to flow from the bottom to the sides of the saucepan.



8.5 Finishing the stove construction

- Plaster the stove body to give it a good finish.
- Use wet fingers or a wet trowel to smooth the finish such that the stove is completely without cracks.
- Ensure that the stove's top surface is uniformly horizontal. Use the spirit level if available (optional).



- Leave the stove block to dry for 4 weeks, while covered with a watertight material e.g. polythene sheet (*kavera*) or banana leaves.
- The stove should be shielded from sunshine.
- Do not allow children or animals to play on or near it.

After about 4 weeks of drying;

- Remove the now shrunk banana stem pieces from the stove body.
- Smooth the hot gases passage (including combustion chamber) using wet hands.

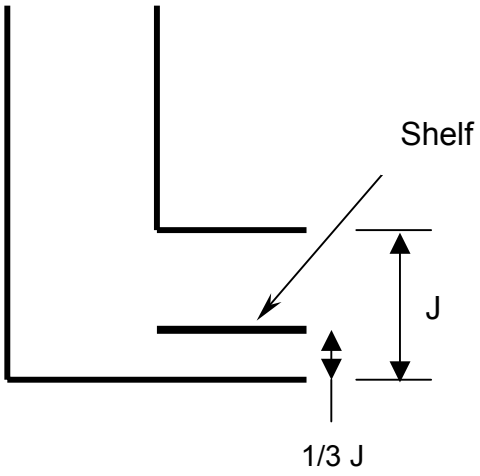
By this time the stove body may have cracked during the drying process, seal the cracks using the original form of mixture that was used to build it.

The outside finishing of the stove body may be made using the methods commonly applied for the finishing of mud walled huts in the community e.g. using a mixture of sand, cow dung and water. This helps to prevent the stove body surface from developing cracks and it also makes it fairly watertight.

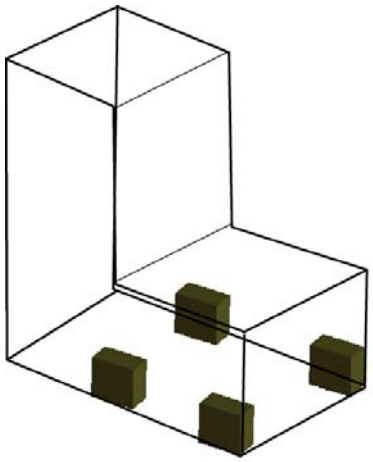
9.0 Fitting the firewood shelf

- Fit a firewood shelf in the combustion chamber.
- It should be positioned 1/3 way up the firewood feed chamber (firewood magazine). Its supports should be built such that the firewood shelf rests at the height shown in the diagram.
- Example: for a 12 cm combustion chamber, J = 12 cm.

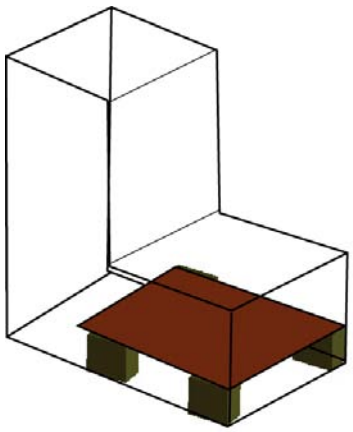
  Therefore 1/3 J = 1/3 X 12 cm = 4cm



- Build the shelf supports as shown



- Then fit the shelf inside



- Preferably use a clay fired tile for the shelf.
- The local brick and clay ventilator makers are capable of making the tiles when given the required tile measurements.
- The clay tile width is 1cm less than the combustion chamber width, to ease sliding in and out.
- Example: for a 12 cm wide combustion chamber, the shelf (tile) width = 12 cm – 1 cm = 11 cm.
- The shelf length should be such that it is just level (flush) with the vertical section of the combustion chamber.

A clay fired tile

10.0 Using the stoves

Using the rocket – lorena stove

Using the shielded fire stove

The stove is now ready for use. It is suitable for use in cooking common types of food including bananas *(matooke)*, potatoes, cassava, beans, *posho* etc.

It may not be suitable for use in roasting.

When using the stove it is advisable to use small amounts of dry chopped firewood. It is also important to observe the following recommendations:

10.1 Efficient cooking practices

- Always use dry firewood split into thin pieces. Wet firewood loses its heat value in driving off excess water. It also produces a lot of polluting smoke.
- Always use a saucepan lid to cover food when cooking. This creates cooking pressure leading to faster softening of food and saving fuel.
- Cut the food into smaller pieces. The technique reduces the amount of energy required to cook.
- Soak the dry-preserved foods (beans, peas, etc) for at least 5 hours, before starting to cook. This cuts down the amount of energy to cook such kind of food.
- Avoid filling too much water in the saucepan. It takes a lot of energy to boil it, hence fuel wastage.
- Light the fire after preparing the food for cooking.

10.2 Cleaning the stove

The stove should be cleaned only when it is not in use (i.e. it should be cold).

- **Saucepan seat(s) and fire passages**
  Sweep out the soot and ash from the saucepan seats at least twice a week.

- **Combustion chamber**
  Slide out the firewood shelf and remove the wood ash from the firewood feed chamber. Place back the firewood shelf after removing the ash. This should always be done before lighting the fire.

- **Chimney (for the Rocket – Lorena Stove only)**
  Get a dry banana leaf; remove the lamina from the mid rib. Bend the mid rid at many points along its length to make it soft. Insert it into the chimney from the top (outside the kitchen). Push it down the chimney and lift it out several times. This will remove the soot from the chimney. Collect the soot from the bottom of the chimney through the second pot seat and remove it from the stove. This should be done every 2 weeks to avoid clogging.

Note: The chimney is brittle because it is made from mud. Care should be taken to avoid breaking it during the cleaning process.

Summary of cleaning schedule

Stove Part	Frequency of cleaning	Purpose
Saucepan seats	At least twice a week	Remove soot and ash
Chimney	After 2 weeks	Remove soot
Combustion chamber	Always before lighting fire	Remove wood ash
The stove body	At least twice a week	Remove dust

10.3 Stove maintenance and repair

It is advisable to perform regular stove inspection to identify faults and provide the necessary remedy to check further damage.

Stove Part	Fault to be checked
Chimney (rocket – lorena)	Wear and tear
Combustion chamber insulation	Cracks, wear and tear
Firewood shelf	Cracks in tiles, wear and tear
Saucepan seat	Wear and tear
Saucepan supports	Wear and tear
Stove body	Cracks, wear and tear

The Rocket – Lorena and Shielded Fire Stoves will bring joy to your home!

APPENDIX 1

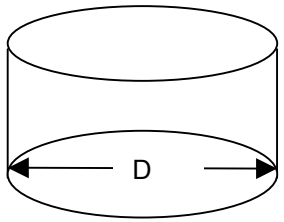
Calculation to determine the diameter of a circular combustion chamber

For a circular combustion chamber equivalent to a 12 X 12 cm combustion chamber,

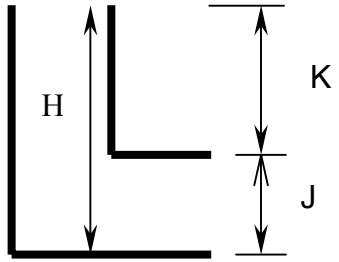
12cm X 12 cm = 144 cm^2
Similarly π X r^2 = 144 cm^2, from which r^2 = 144 ÷ 3.14 = 45.8 cm^2,
Consequently r = $\sqrt{}$ 45.8 cm^2 = 6.8 cm and diameter = 2 X r = 2 X 6.77 ≈ 13.5 cm

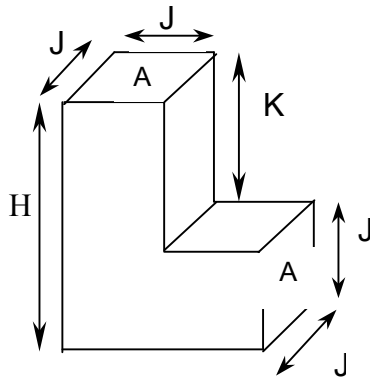
APPENDIX 2

Pot Diameter D (cm)	Pot capacity (litres)	J (cm)	K = 1.5 X J (cm)	H=K+J (cm)	Banana stem diameter (cm)	Chamber Area (cm^2)	Chamber Sizing
Up to 20	Up to 2.7	11	16.5	27.5	12.4	121	11 x 11 cm
21 - 27	2.7-7.5	12	18.0	30.0	13.5	144	12 x 12 cm
28 - 30	7.5-9.8	13	19.5	32.5	14.7	169	13 x 13 cm
31 - 35	9.8-15.7	14	21.0	35.0	15.8	196	14 x 14 cm
36 - 40	15.7-24	15	22.5	37.5	17.0	225	15 x 15 cm
41 - 50	24-35	16	24.0	40.0	18.0	256	16 x 16 cm
46 - 50	35-47	18	27.0	45.0	20.3	324	18 x 18 cm



Saucepan





Area = Length X Width
A = J X J

The rocket elbow combustion chamber

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